QUALITATIVE AND QUANTITATIVE STUDIES ON THE ROOT SYSTEM OF FESTUCETUM VAGINATAE

by

T. SIMON and K. H. BATANOUNY

Department of Plant Taxonomy and Ecology of the Eötvös Loránd University, Budapest

College of Science, Baghdad University, Irak

Received on 15th September, 1970

Introduction

In the Department of Plant Taxonomy and Ecology ecological and production-biological investigations on sandy plant-communities have been carried out for several years (Simon – Kovács-Láng 1964, 1968, Simon – Fülöp 1966, Kovács-Láng 1970). In 1968 the open perennial sandy sward *(Festucetum vaginatae)* and the phytomass production of the annual sandy sward *(Brometum tectorum secaletosum)* were studied. In this paper part of the results of these investigations, carried out in June, July, and August, as well as the results of the morphological-structural studies conducted for two years are presented in order to indicate the complementarity of these two methods.

The plants in the studied area are subject to more or less adverse moisture conditions. Therefore a study of the depth and extension of the root systems of plants growing under these conditions is important. The importance of such studies was claimed by numerous authors (Weaver 1919, Pavlychenko 1937, Albertson 1934, Abdel Rahman 1953, Abdel Rahman – Batanouny 1959.)

In addition to a study of the root systems of individuals of any species investigations on the root systems and root habits within the community as a unit also seem to be important. Such studies will elucidate the interaction and competition among the plants, particularly those with the same requirements.

In the investigation area water may be the most important factor. The variability of rainfall from year to year and the irregular distribution of rainfall in the different months, play an important role in plant life. The depth and lateral extension of roots are not only dependent mainly on the amount of annual rainfall, but also on the monthly distribution of rain in the rainy season and on the water content of the soil strata (cf. Kovács-Láng – Szabó 1971).

Methods

The studied sites were chosen on the tops of the sand accumulations inhabited by *Festucetum vaginatae*. (Fig. 8. 9. 10.) A straight line, 2.5 m long, was marked on the soil surface. This distance was found to be sufficient to cross the important species growing in the studied area.

The choice of the localities was at random within the boundaries of the association.

A trench, 2.5 long, 75 cm wide and to a depth of about 80 cm, was dug. This was conducted three times at the beginning of the work in order to record the depth of penetration and lateral extension of the roots of different species. The soil was removed until the entire root systems of plants crossed by the straight line were exposed. The root and shoot systems of these plants were drawn to scale.

Excavations and drawings were conducted in two successive years during summer, namely 1968 and 1969. In the first year, this was made in June and August, while in the second, in July and August. Figs. 1, 2, 3 and 4 show the root systems in these months, respectively.

Simultaneously, samples were taken in order to establish the subterranean and supraterranean production. $20\times20\times20$ cm monoliths were taken out from the soil of the community (on one occasion 10 samples monthly from which the shoots of the seedplants have been gathered by the harvesting method (cutting), while the mosses and lichens were collected by the piece. The total plant material was weighed, without separating the species, in air-dried condition. The production thus gained for three months (June, July, August of the year 1968 is shown in (Figs. 5, 6, 7, Table 1). For the year 1969 only control samples (5 samples collected in August are shown). In the Tables and Figures presenting the data for the year 1968, the values of the annual open sandy sward are also shown for the soke of comparison. It has to be mentioned that in this deep and loose sandy soil the root-system penetrates considerably deeper than 20 cm. However, just the joined morphological and quantitative studies prove that the majority of the roots, about their two-third, are located in the upper stratum reaching from 0—20 cm, and only one-third is below this (cf. Précsényi 1967, Máthé 1968, Máthé — Précsényi — Zólyomi 1967).

Results

Root Systems of Different Species

Magyar (1936) studied the root systems of plants inhabiting sandy soils. Not further studies on the root systems of these plants were conducted. In the present investigations root systems of 15 species were studied, including perennials, one biennal and ephemerals.

A brief description will be given for the root systems of these species. The description refers to any average individual.

Festuca vaginata

This species has a dense, fibrous root system of tough and strongly branched roots. Many roots originate from the base of the plant and have an average depth of 30 cm, some of them may penetrate further to a depth of 60 cm.

The roots of a mature individual exploit a soil column with a diameter of 30 cm. The laterals spread obliquely in the soil and produce thousands of short laterals. The maximum number of laterals occupies the soil at a depth from 5 to 20 cm.

The shoots trap soil material round the plant body leading to the elevation of the soil surface about 2 to 5 cm above the original level. This small mound is impregnated with dead plant material causing its enrichment in humus content. Pedogenic changes due to the growth of *Festuca vaginata* and the associated grasses may lead to changes in the organic carbon content, soil texture and colour. L á n g (1969) found that the humus content in the upper layers of soils inhabited by *Festucetum vaginatae* was 0,85% while amounted to 0,20% in deeper layers.

The root to shoot ratio is relatively high. The average height of a plant ranges from 10 – 20 cm excluding the inflorescence, while the roots penetrate as deeply as 40 or 60 cm.

Koeleria glauca

Contrary to *Festuca,* large number of laterals are restricted to shallow depths of about 10 cm. A limited number of roots penetrate more deeply than those of *Festuca* reaching about 50 or 60 cm. The roots in *Koeleria* originate from a condensed rhizome lying below the soil surface. The roots produce numerous short laterals.

Soil material is accumulated around the shoots causing slight elevation of the soil surface. Soil changes similar to those caused by *Festuca* are observed but to a shallower depth.

The root to shoot ratio is higher than in *Festuca*. The height of shoots amounts to 10 cm and roots penetrate to a depth of about 50 cm. The production of deeply penetrating laterals may play an important role in the water economy of this species.

Stipa sabulosa

Roots of this species penetrate deeper than those of other associated grasses. Moreover, the root system of a mature individual exploits larger soil volume than *Festuca* and *Koeleria* do. The roots are produced from the bases of the tillers having wiry, tough structure and are light-coloured. The roots are thicker than in other grasses and produce longer laterals which may rebranch into short ones. The root system of this species absorbs water from deep layers at 60 cm below the soil surface. The lateral extension amounts to 30 cm on both sides.

The root to shoot ratio is the lowest among the studied grasses. The height of the plant ranges from 30 to 60 cm which is the highest in all the grasses in the studied site.

Carex liparicarpos

Individuals of this species grow a few cm apart and are connected by a more or less horizontal system of underground thin rhizomes. Opposite to the aerial shoots, there are numerous roots which show different directions of penetration. Some roots travel horizontally at a depth of about 5 cm for a distance of 15 cm, while others are larger, but fewer in number and penetrate the soil vertically till a depth of 40 cm or more. Both roots produce numerous laterals, but those of the vertical roots are longer and may branch into short ones.

The lateral spread of the underground parts in indefinite. The root to shoot ratio is high in this plant. This may compensate for the great water loss by the leaves.

Potentilla arenaria

This species has underground stolons running parallel to the soil surface at a shallow depth of about 2 cm. These stolons produce aerial shoots at every other node and roots at every node. The roots penetrate obliquely in the soil and reach a depth of about 30 cm. The maximum density of *Potentilla* roots is in the uppermost 20 cm layer of the soil.

Numerous individuals, though apart from each other, may be connected by the underground parts. The lateral spread of these stolons is unlimited.

The root to shoot ratio is considerably high. The height of the shoot never exceeds 5 cm, while the roots occupy large soil volumes.

Fumana procumbens

The root system of this species is formed of a deeply penetrating tap root with numerous laterals. These laterals are produced nearly all over the whole length of the main root which extends till a depth of 60 cm. Plants probably absorb mostly from depths greater than those densely occupied by the roots of grasses. At least their effect upon grasses is usually not marked except where they occur in unusually dense stands.

The root to shoot ratio is very high. The shoots are usually stunted, not exceeding 10 cm in height.

Euphorbia seguieriana

The rooting habit of this species is highly interesting. It has a stolon with a swollen part a t a depth of about 10 cm. Numerous branches originate from this swollen part. Some of them penetrate deeply producing many laterals which in turn branch. Others may comprise several individuals connected by their underground stolons. Small rootlets may originate from these stolons, especially when the soil is moist. The depth of penetration of the root system may amount to 60 cm.

Dianthus diutinus

The primary root is not so prominent in this species. Its thickness decreases rapidly with increasing depth. It penetrates to a depth of about 30 cm.

At shallow depths of about 5 cm, numerous long laterals are produced. These laterals extend more or less horizontally with a length of 40 cm. Other laterals which are thin and short are produced from the main root from depths greater than 5 cm.

Biennial and Annual Species

Roots of annual plants are all quite shallow. Most of them do not penetrate to depths greater than 25 cm. Usually the laterals are more prominent.

In case of biennial species as *Syrenia cana*, the root system penetrates to depths greater than annuals amounting to 40 cm.

Annual grasses as *Setaria lutescens* have shallow fibrous roots produced from the bases of the plants.

Some species as *Solidago* or *Tragopogon* have tuberous roots nearly below the soil surface. These fleshy roots produce some laterals which travel horizontally at shallow depth.

Root Habits within the Community

It is a well-known fact that the layering of roots reduces competition and permits the growth of a larger number of species. Though the majority of roots are restricted to the upper 20 cm, yet some species produce deeply penetrating ones.

The vegetation inhabiting the studied site comprises different perennial categories of plants, i. e. grasses, forbs, annual plants, mosses and Lichens.

Though the roots of grasses are concentrated in the upper 20 cm, yet one can consider that every species has roots absorbing from different layers. For example, *Festuca* roots exploit mainly the upper 20 cm, *Koeleria* roots benefit from the soil moisture at two different depths, a shallow one (10 cm deep) and a deeper one below the level of *Festuca* roots. *Stipa* roots absorb water from different levels down to a depth greater than that reached by roots of other grasses. Though there is no evident stratification in the root systems of the other main grasses, yet they absorb water from different levels.

This is due to the concentration of *Festuca* roots in the upper 20 cm, the production of deeply penetrating roots in *Koeleria* and the wide spreading of *Stipa* roots.

Forbs usually have deeper root systems absorbing water from depth far below those reached by the roots of grasses.

With respect to the ephemeral species, they have their root systems mainly in the upper 20 cm. This means that there will be competition for water among their roots and those of perennials. But it must be taken into consideration that ephemerals will not germinate and complete their life cycles except after sufficient rainfall. Under such conditions, there will be adequate water supply for both perennials and ephemerals. Even if these ephemerals germinate and are then confronted with a drought period, they will vanish rapidly. So, the growth of ephemerals and their root extension will not affect perennials under humid conditions. Under dry conditions, however, ephemerals disappear rapidly.

Monthly and Annual Morphological Variations in the Root Systems

The effect of soil moisture on root growth, lateral extension and depth of penetration is extremely high. As rainfall in the studied area is characterized by its irregularity, there will be irregular fluctuations in the soil moisture. The annual rainfall in the years 1968 and 1969, as well as in the different months in both years, are widely different. These differences are reflected by the density of the vegetation, vigour of the plants and the root density in the soil.

The data shown in Figs. 1, 2, 3 and 4, reveal that the density of the roots as well as the heights of the shoots are higher in 1969 than in 1968. Due tohigher rainfall in spring and early summer in 1969, root growth was accelerated. This may be attributed to the greater transpiring surfaces of the plants, so laterals are produced to give greater absorbing surface.

Figs. 1 and 2 represent the root systems in June and August, 1968, respectively. These Figures show different. This may be due to the summer rains during July and August, 1968. In June 1968, the root systems were shallow and not so dense as in August in the same year. Moreover, the annuals are stunted and shallowly rooted. On the other hand, in August 1968, the roots are deeper and their density is higher than in June in the same year.

In the year 1969 the root systems in July are deeper and more dense than in August in the same year. This is due to the limited showers during that period and the desiccation of the upper layers. As stated by Reed (1939), the periods of the slowest root growth in summer coincide with the periods of lowest soil moisture.

Comparative investigations of the productivity of the root system

Our investigations carried out in 1968 prove that in the layers studied the growth of both the supraterranean and subterranean organics parts show a definite yearly rate (cf. Kovács-Láng – Szabó 1971). The maximum of the underground parts precedes (May) the maximum of the parts above the soil of the plant communities on those warm, loose

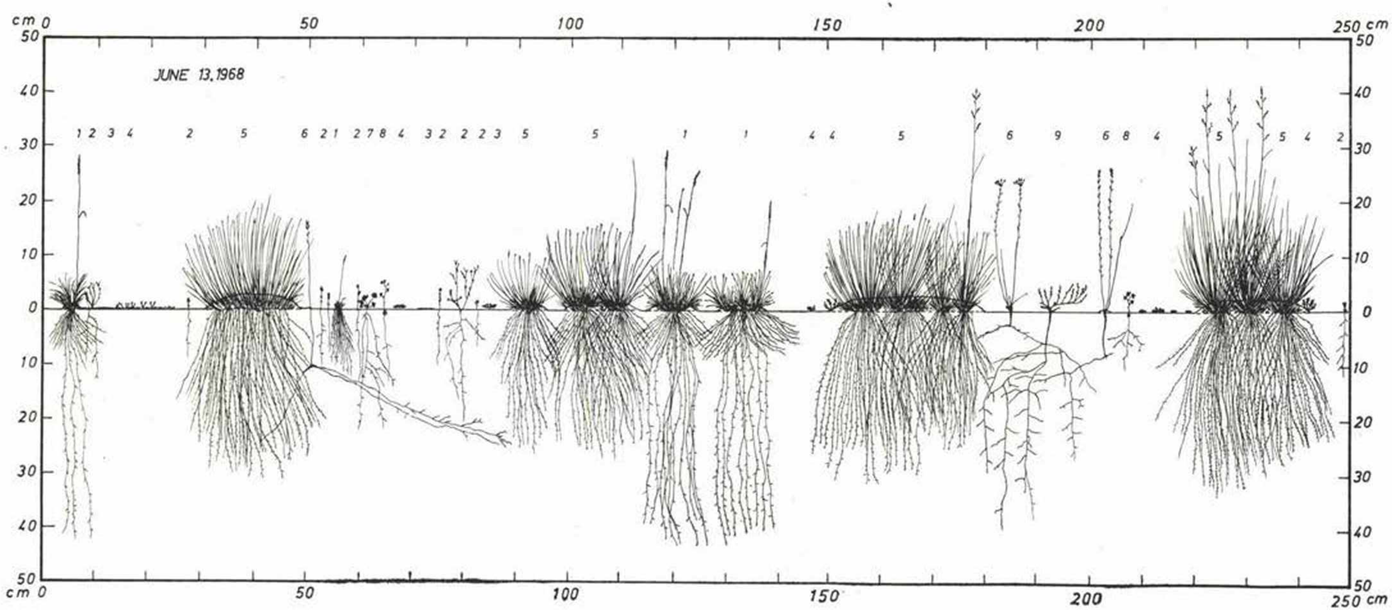


Fig. 1. The structure of the stand in open perennial sandy sward *(Festucetum vaginatae)*, along the 250 cm transsect, *1968 June*. For further details see legend to Fig. 4.

1 = *Koeleria glauca*, 2 = *Minuartia verna*, 3 = *Bryophyta* (mainly *Syntrichia ruralis*), 4 = *Lichenophyta* (mainly *Cladonia foliacea, C. furcata*), 5 = *Festuca vaginata*, 6 = *Euphorbia seguieriana*, 7 = *Potentilla arenaria*, 8 = *Medicago minima*, 9 = *Fumana procumbens*, 10 = *Polygonum arenarium*, 11 = *Stipa sabulosa*, 12 = *Setaria lutescens*, 13 = *Syrenia cana*, 14 = *Carex liparicarpos*, 15 = *Alyssum tortuosum*, 16 = *Dianthus diutinus*, 17 = *Solidago virga-aurea*

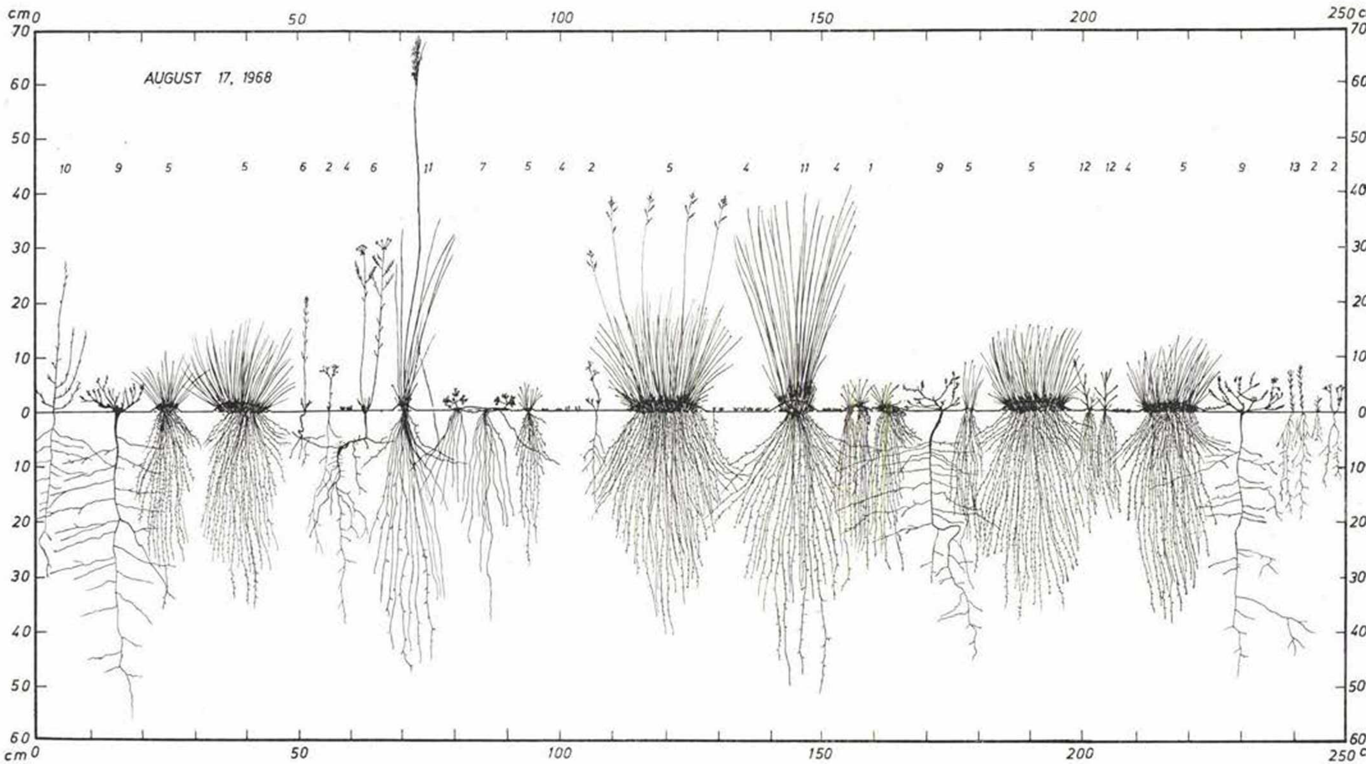


Fig. 2. The structure of the stand in open perennial sandy sward *(Festucetum vaginatae)*, along the 250 cm transsect, *1968 August*. For further details see legend to Fig. 4.

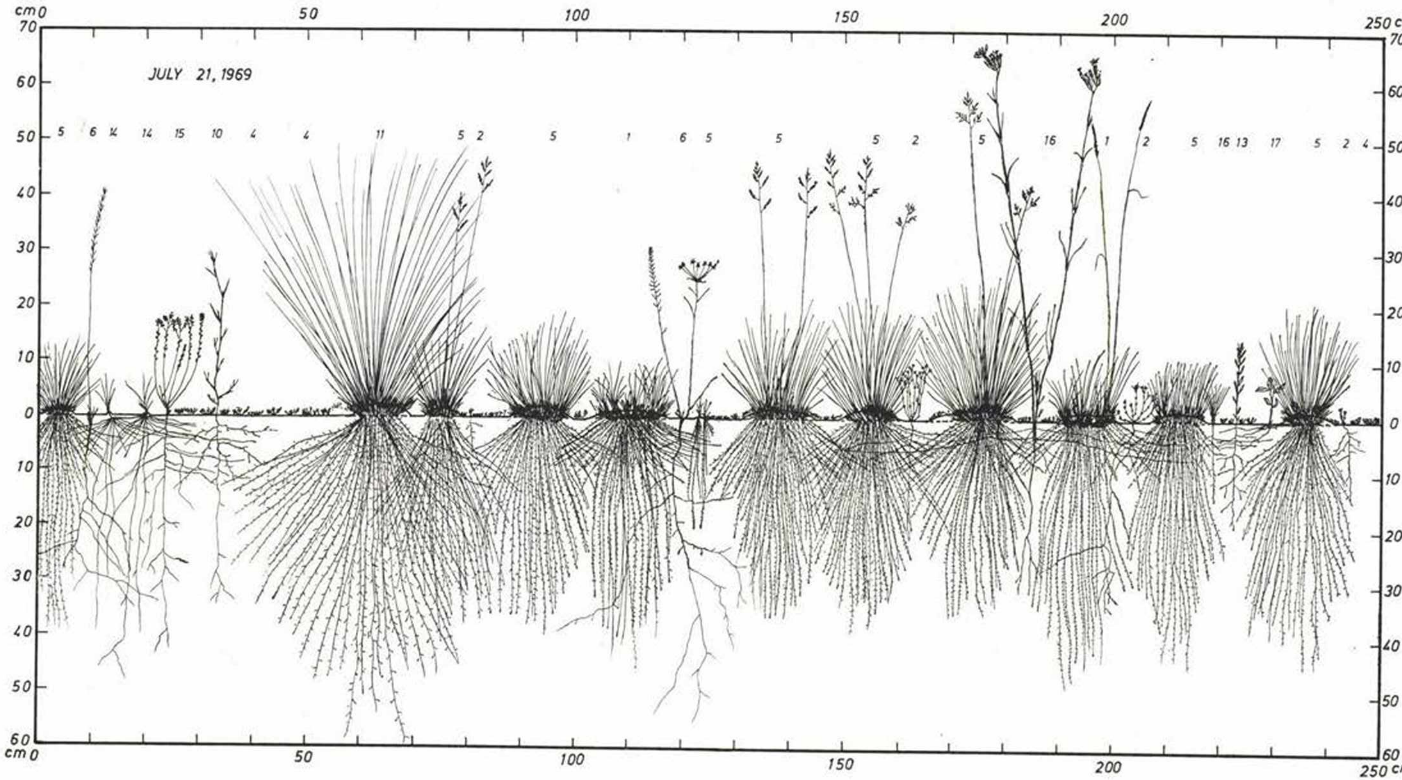


Fig. 3. The structure of the stand in open perennial sward *(Festucetum vaginatae)*, along the 250 cm transsect, *1969 July*. For further details see legend to Fig. 4.

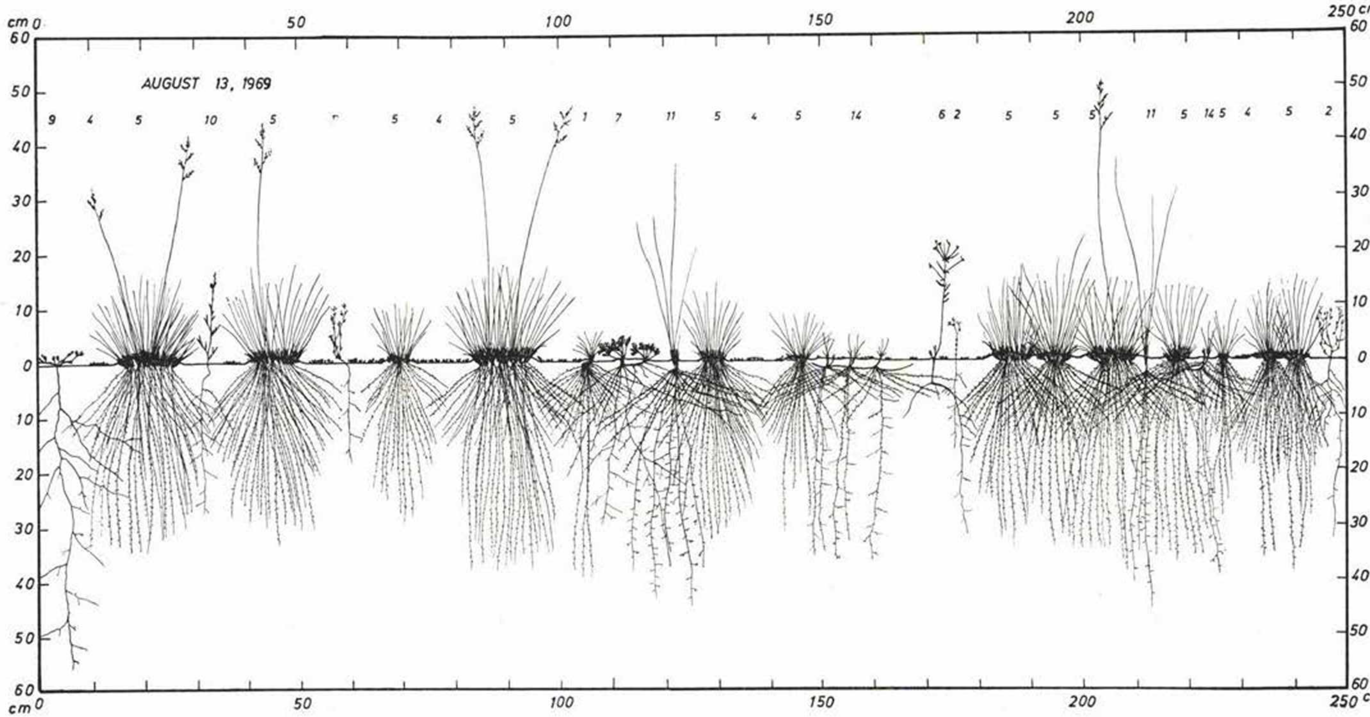


Fig. 4. The structure of the stand in open perennial sandy sward *(Festucetum vaginatae)*, along the 250 cm transsect, *1969 August.*

sandy soils, the maximum occurring in summer (July). On the colder and harder Hortobágy alkali soils the maximum of root development occurs in August (Précsényi 1969).

Figures 5, 6, 7 and Table 1 make it possible to compare the data of the perennial open sward *(Festucetum vaginatae)* with those of the annual open sward *(Brometum tectorum secaletosum* with respect to the supraterranean and subterranean productions.

The supraterranean production (Fig 5) is, in both communities, the highest in July, while the subterranean production is, in the months in question, the highest in June. In August both (supra- and subterranean) show a decreasing tendency. This is clearly visible in the graph representing the mean values (Fig .7) and in Table 1. where the values are expressed as production per square meter.

The values obtained for the samples in the case of phytomass (Fig. 5) showed, in both communities, greater differences in July indicating that the highest intensity of growth falls to this time. The values for the root systems (Fig. 6) show the considerable structure difference of the two communities. The data of *Brometum* are more steady indicating the more homogene homogeneous pattern of the individual plants, while the samples of *Festucetum vaginatae* show greater differences indicating the inhomogeneous distribution of the larger perennial plants in the more open swards. This means also that in this association, for a more reliable evaluation of the yearly rate, it would be to the purpose to increase the number of samples and the size of the sampling area.

From a comparison of the values obtained for the supraterranean and subterranean productions and the structural-morphological drafting, it can be seen that about 2/3 of the roots are in the upper 0 – 20 cm layer of the soil. On this basis there seems to be a possibility for a correction, i.e. for the estimation of the real value of root production, under the given conditions, about 50% (cf. Table 1.) must be added to the measured values.

The tendency for increase that can be seen in the 1968 Figures concerning the structural-morphological exposure, is partly contradictory because the July picture is missing; that of the 1969 Figures entirely agrees with the rate of the summer phytomass production data in the year 1968.

This is, most probably, related with the rainfall distribution of the area examined.

Precipitate in mm

Month	1968	1969
May	15	30
June	25	130
July	35	30
August	130	80

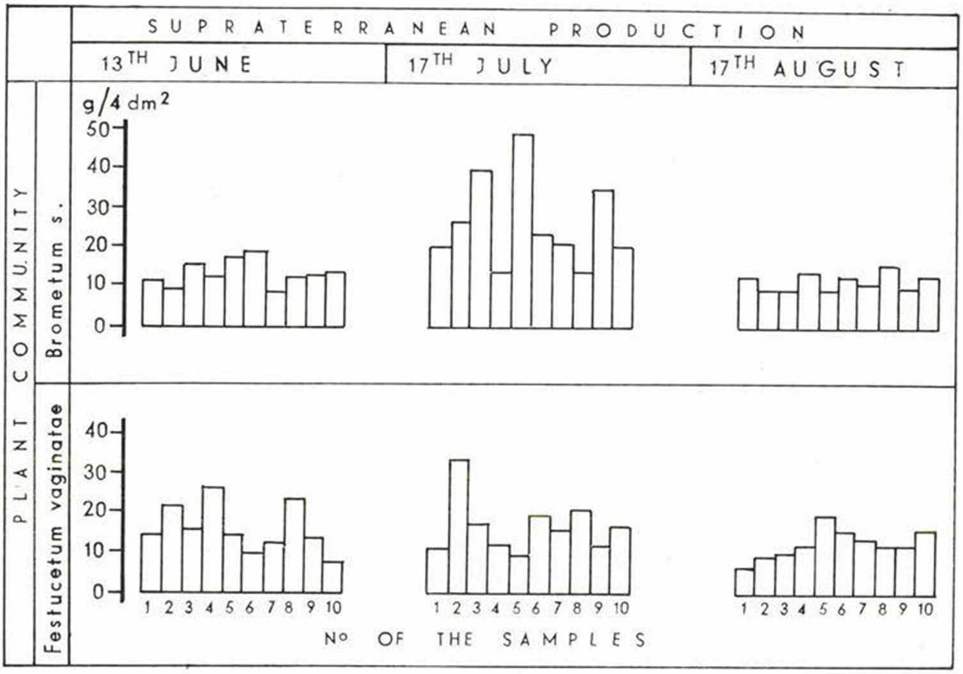


Fig. 5. Comparative graphs of the supraterranean phytomass production in the 4 dm sampling areas, 1968.

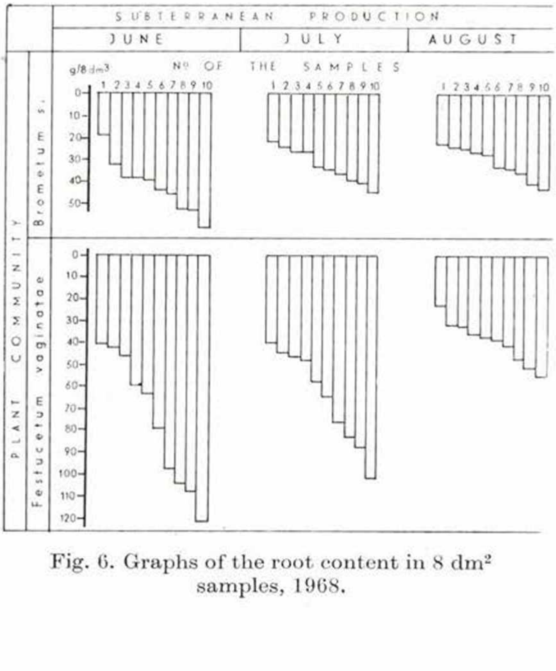


Fig. 6. Graphs of the root content in 8 dm² samples, 1968.

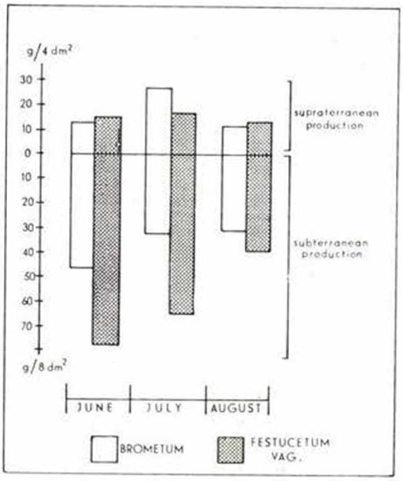


Fig. 7. Mean values of the supra-and subterranean phytomass production, the samples being gathered from the two communities, 1968.

It can be supposed that the density of the roots is not in direct proportion to the weight of the same roots. In the case of younger root systems the same density might give rise to more weight, while old older roots have less weight. The agreement in the year 1969 between the quantitative (1968) and structural-morphological examinations might also be explained by the fact that at that time the morphological transsects exactly overlapped the area of quantitative sampling, while in the previous year they were by about 100 m further, in a somewhat more sheltered (by forest) environment. It has to be observed that average of the quantitative control samples collocted in August 1969, is in good agreement with those of the previous year:

Phytomass Production of *Festucetum vaginatae*, dry weight in g/m²

	August, 1968	August, 1969
Supraterranean Production	332	367
Subterranean Production	973	943

The July maximum is in the supraterranean production in both communities. Suggests that the root maximum measured in June in the upper rhizosphere was correct. It can be supposed that root development occuring in August, in the deeper strata, is a forerunner of a later supraterranean development under the effect of ample rainfall in August.

From the above it can be concluded that, with quantitative examinations, the depth of sampling can hardly be increased because of method methodological differences, – it is to the purpose to complement the quantitative methods applied into the phytomass examination with a suitable number (at least 3-times a month) of structural-morphological investigations. In this way the results will be more accurate.

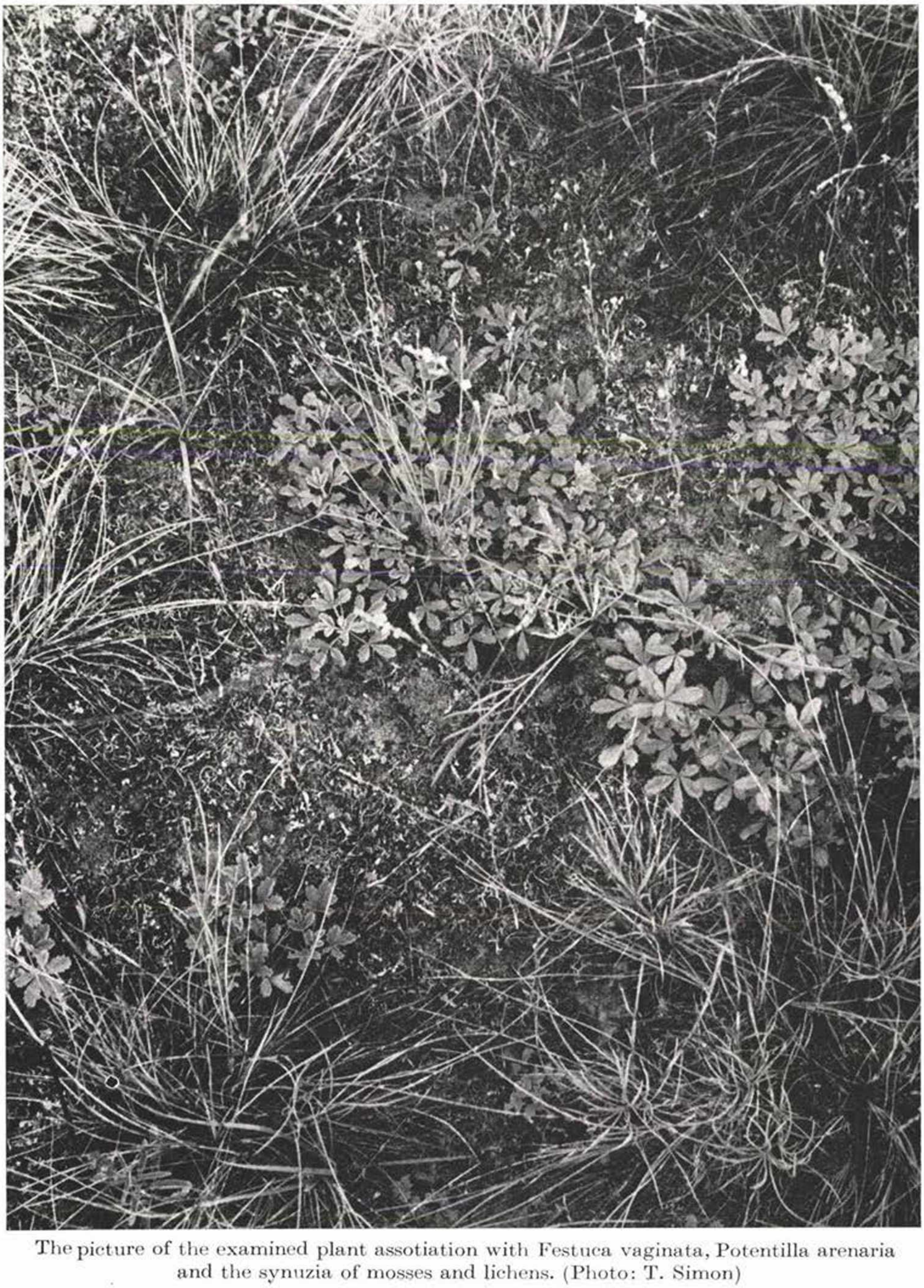
On the basis of the present examinations, for the estimation of the *entire subterranean production* of *Festucetum vaginatae successive corrections* might be suggested, in June +45%, in July +50%, in August +55%!

Conclusions

The vegetation in the studied area is open to a certain extent, a character which has an important value in water economy.

Plants inhabiting this area have different types of root systems with respect to depth of penetration and lateral extension. This reduces competition among the plants.

The roots of grasses, though without definite layering, absorb water from different layers. *Festuca* roots exploit mainly the soil layer from 5 to 20 cm deep. *Koeleria* roots absorb water from two different depths, a shallow one at 10 cm depth and a deeper layer at a depth of 50 cm. *Stipa* has widely spreaded root systems.



The picture of the examined plant assotiation with Festuca vaginata, Potentilla arenaria and the synuzia of mosses and lichens. (Photo: T. Simon)

Both photos (above and below) about the nature conservation area of Csévharaszt with sandy forest-steppe vegetation. (Photo: T. Simon)

Forbs have deeply penetrating roots absorbing water from deeply seated layers.

Annual species have shallow roots and vanish due to the desiccation of the upper soil layers.

The grasses accumulate soil material round their bodies. This leads to some pedogenic changes, mainly to on increase in humus content, darkening in colour and changes in soil texture.

A comparison of the root to shoot ratios shaws that plants in general have a high ratio of root to shoot. This peculiarity is of great importance since the extensive development of roots is regarded as an adaptation for absorbing a sufficient amount of water from as large as possible a volume of soil with low moisture content.

It is clear that in years with low rainfall the vegetion is more open. The widely spaced plants reduce the competition which in turn minimizes the amount of water with drawn by roots per unit volume of soil. The root density is lower in dry years than in wet ones.

On the basis of the quantitative examination of samples taken from the soil of the community and the structural-morphological data, it can be established that about two-third of the roots are in the upper, 0—20 cm layer of the soil. The root content of that stratum decreases from June to August while the mass of the supraterranean parts is the highest in July. The productivity of the one-year old sward is similar. The factors causing the variance of the production samples (at the given sampling) are the inhomogeneous distribution of the species forming the open vegetation, the growth intensity of the species changing in time. The area distribution of the annual sward is more homogeneous.

It seems possible that the maximum in the development of root-masses changes as a function of soil depth. In 1968 the weight increase of the roots in the deeper layers occured in August (Fig. 2). It can be supposed that the density of the roots is not in direct proportion with the weight of the same roots. In the case of younger roots the same density might be associated with higher, while in the case of older ones, with less weight. On the basis of the above it seems to be very advisable to complement quantitative studies with structural-morphological examinations. In this way correction can be made and the whole mass of roots can be estimated.

Table I.

Production	Plant community	Quantity of the Production g/m²		
		13th of June	15th of July	17th of August
Supraterranean	*Brometum*	335	665	308
	Festucetum vaginatae	380 (559)	427 (640)	332 (514)
Subterranean	*Brometum*	1160	824	779
	Festucetum vaginatae	1930 (2799)	1630 (2445)	973 (1507)

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Table 1. Phytomass production per sqare meter, of the annual *(Brometum)* and perennia open sandy sward *(Festucetum vaginatea)*, total supraterranean material + subterranean material to a depth of 20 cm² in the three summer months of 1968. In brackets, the *estimated* (= successive correction) values on the basis of the structural-morphological study of the total *subterranean* production.